Sixth Annual Conference on Carbon Capture & Sequestration

Session: Capture Membranes

The Membrane Solution to Global Warming

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Membrane Technology and Research, Inc.

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Outline

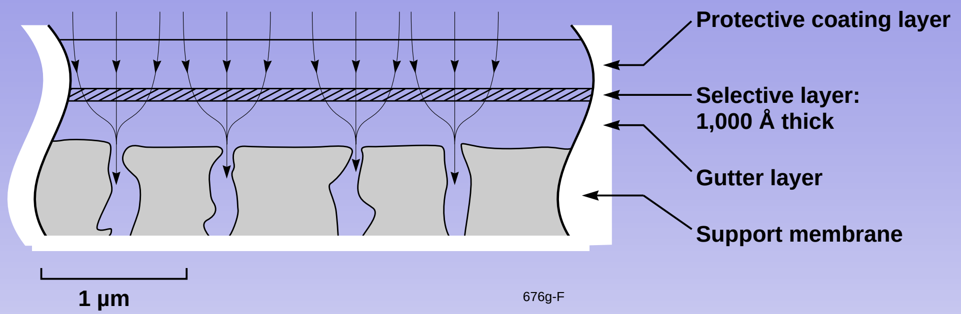
- Introduction to membrane gas separation technology
- Introduction to MTR
- System designs to recover CO_2 from coal power plant flue gas

Membrane technology

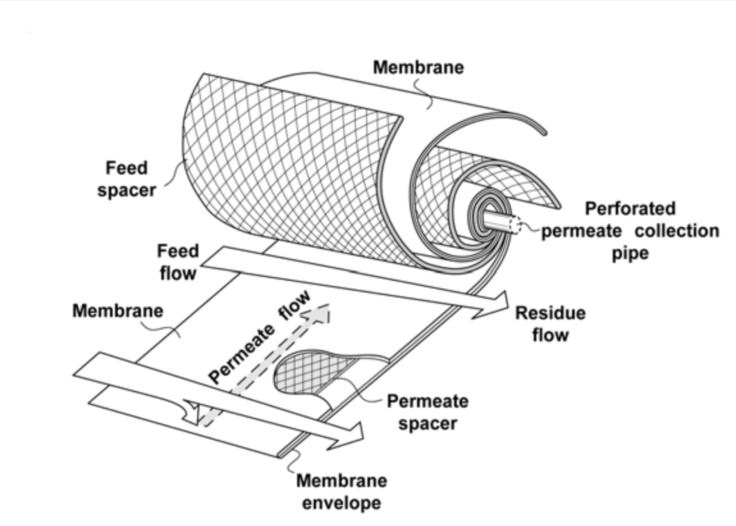
- Industrial membrane separation technology is a $2-3 billion/year industry
- Mostly water treatment, reverse osmosis, microfiltration
- The gas separation business is ~$250 million/year

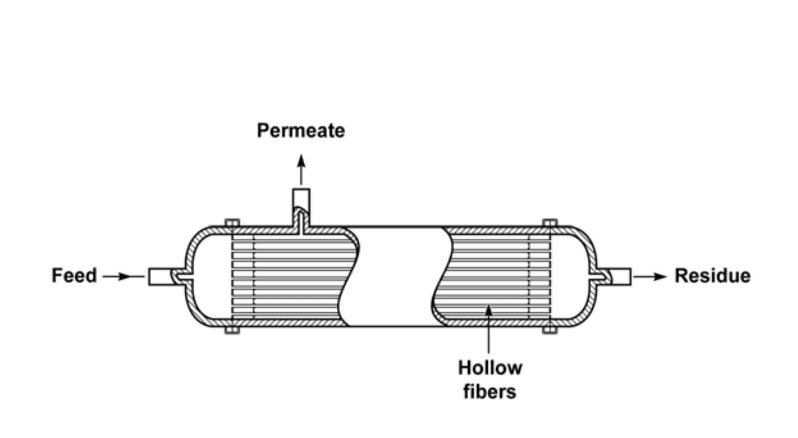
Membrane technology

- Membranes have to be thin to provide useful fluxes



- Spiral-wound and hollow fiber modules are used





MTR

Membrane gas separation plants can be big

- UOP Separex System, 6.5% CO_2 to 2% CO_2
- Treats 500 MMscfd (160 m^3/s) of gas
- ~1/3 of a coal combustion plant
- ~100,000 m^2 of membrane

MTR

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Principal products are separation systems for:

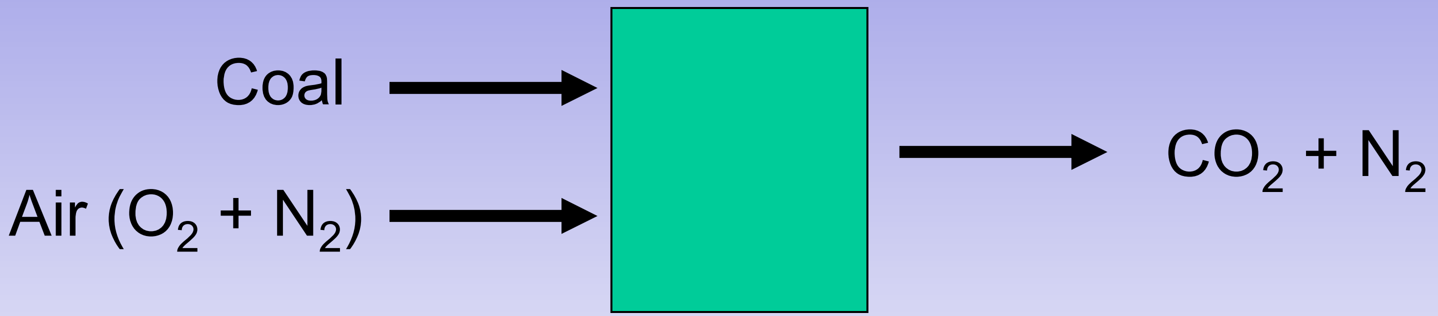
<u>Petrochemicals</u>
Propylene/Nitrogen
Separation

<u>Natural Gas</u>
CO_2/CH_4, CH_4/N_2
NGL/CH_4

<u>Hydrogen (Refinery)</u>
H_2/CH_4, CO

MTR

Coal combustion produces a lot of flue gas



600MW ≡ 500 m^3/s flue gas (13% CO_2) ≡ 1540 MMscfd flue gas

= 460 tons CO_2/h

Target Separations: CO_2/N_2 – Polaris™

Membranes with very high gas permeances are required

Polaris™ (Mixed gas – 30˚C)

Gas	Permeance (gpu)	Selectivity (CO_2/gas)
Carbon dioxide	1,000	--
Nitrogen	20	50
Oxygen	50	20
Carbon monoxide	20	50
Methane	60	17
Sulfur dioxide	>2,000	<1
Hydrogen sulfide	>2,000	<1
Water	>2,000	<1
Argon	50	20

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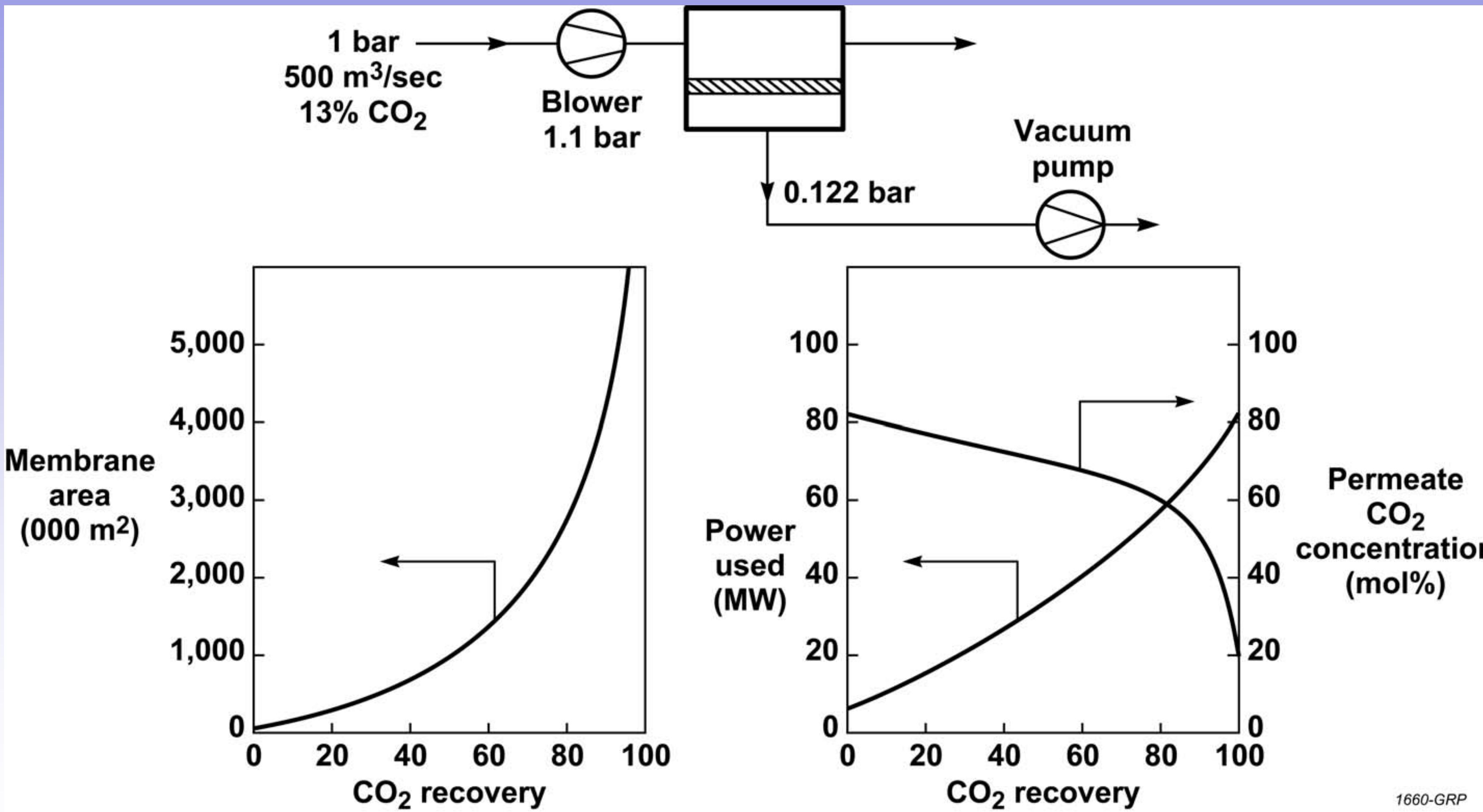
Option I: Vacuum operation uses less power but lots of membrane



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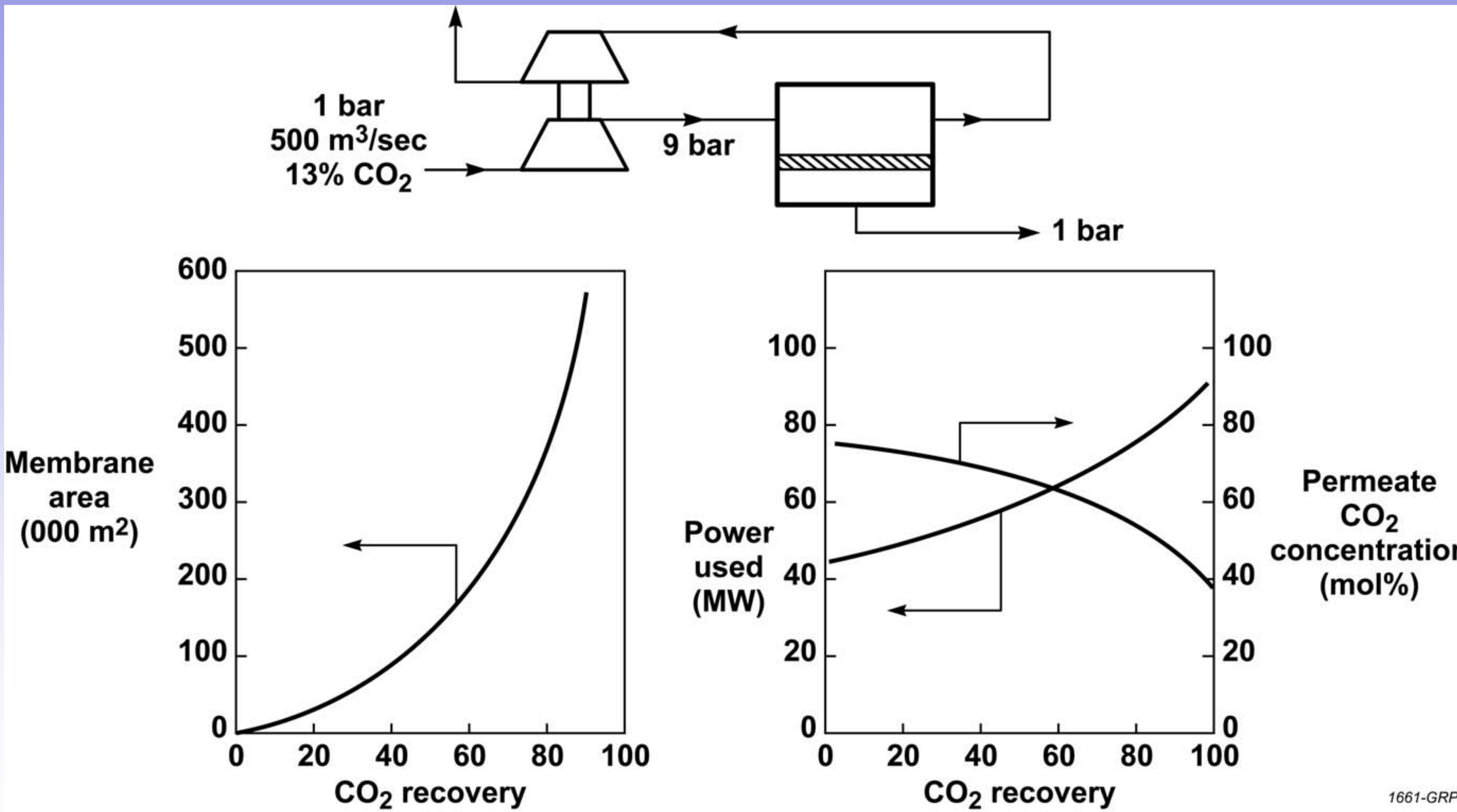
Option II: Feed gas compression uses less membrane but more power



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Process comparison

One-Stage Separation – 70% CO_2 Recovery

Type of Operation	Membrane Area (000 m^2)	Power Consumption (MW) (%)	Permeate CO_2 Concentration (%)
Vacuum operation	1,800	45 (7.5)	63
Compression operation	250	68 (11)	59

- Vacuum operation does not save much power and uses lots more membrane.
- Multi-stage separations are needed to achieve the required separation.

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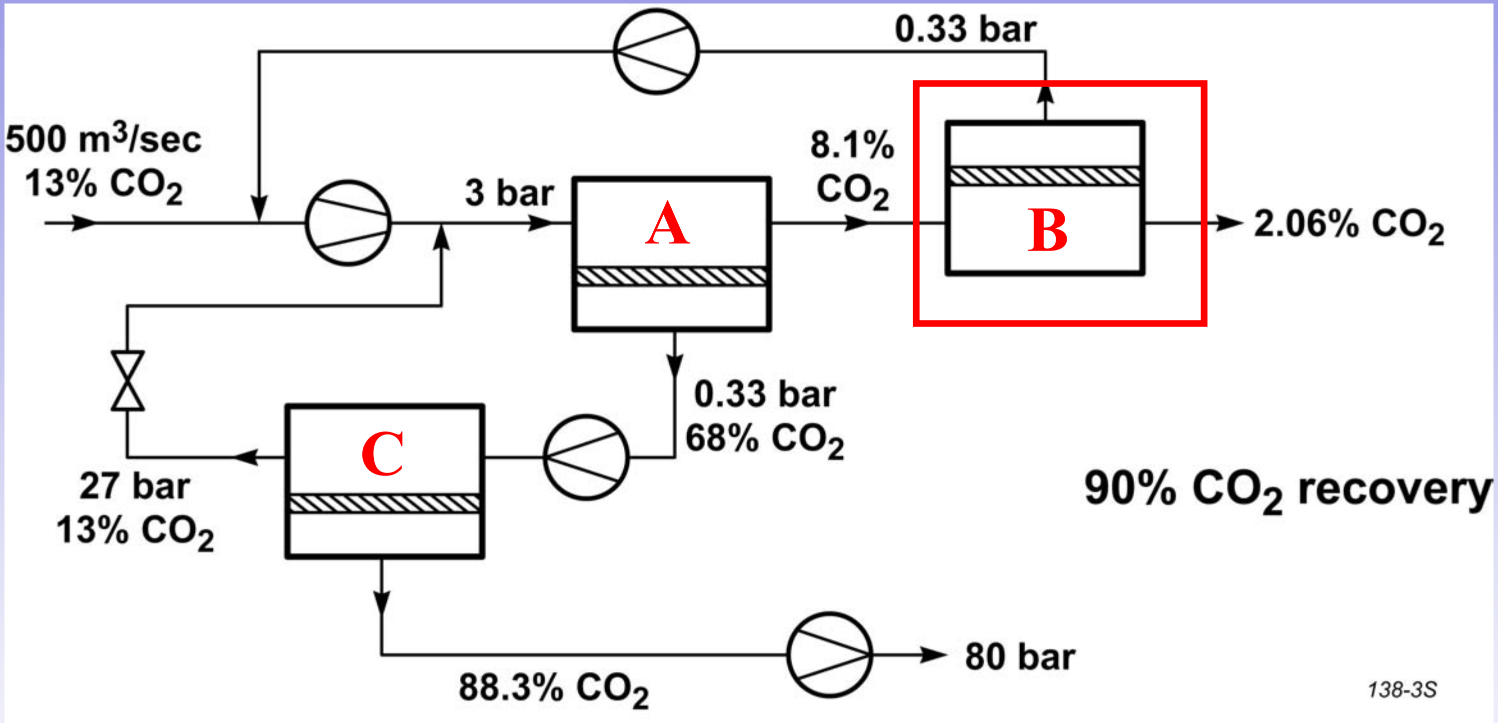
Option III: Two-step, two-stage – with feed compression and permeate vacuum



CO_2 Recovery (%)	Membrane Area (000 m^2)	Power Consumption (MW)*	Cost ($/ton of CO_2)
90	2,070	122	48

*** Power consumption includes the compression of the gas to 80 bar.**

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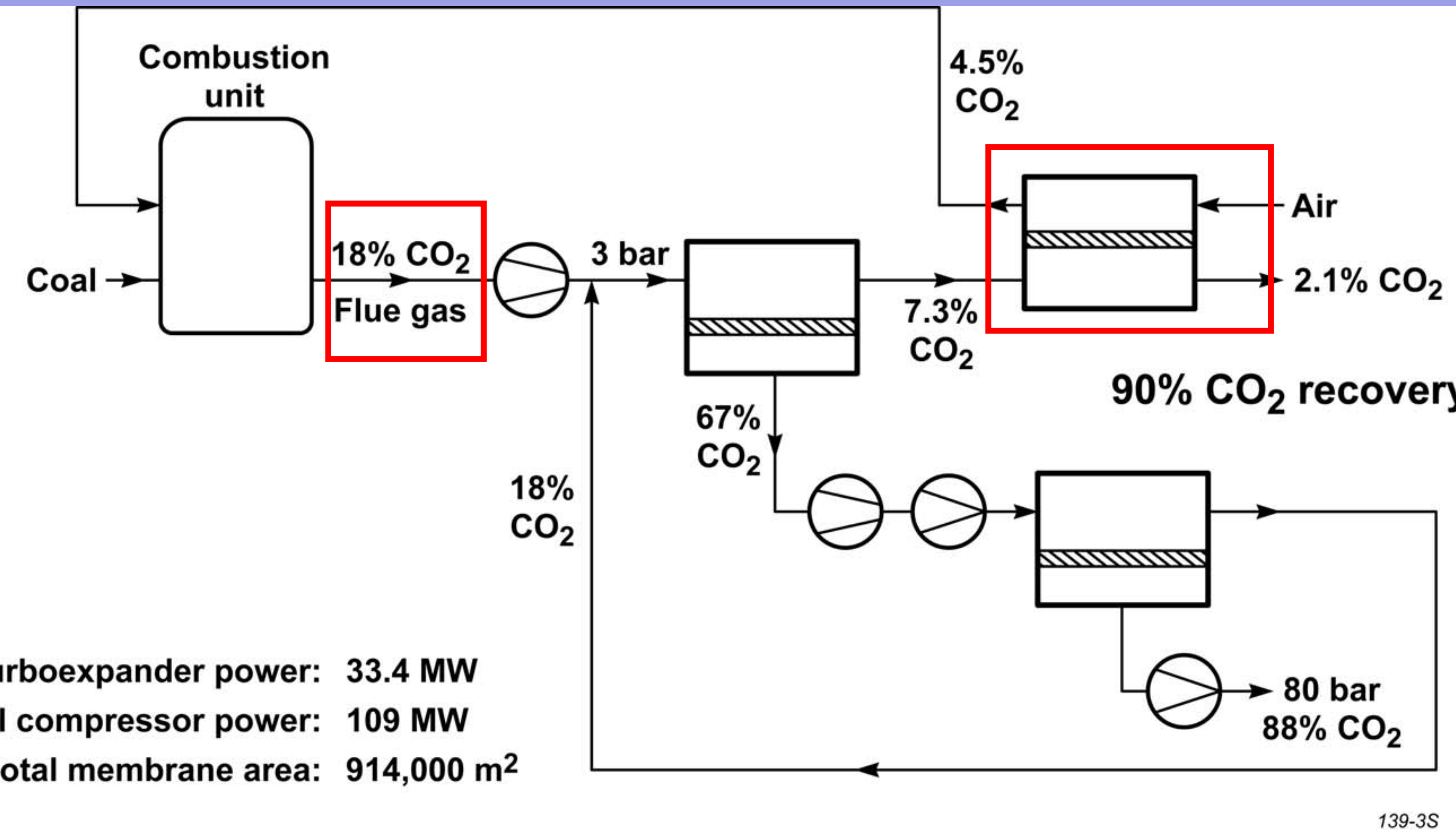
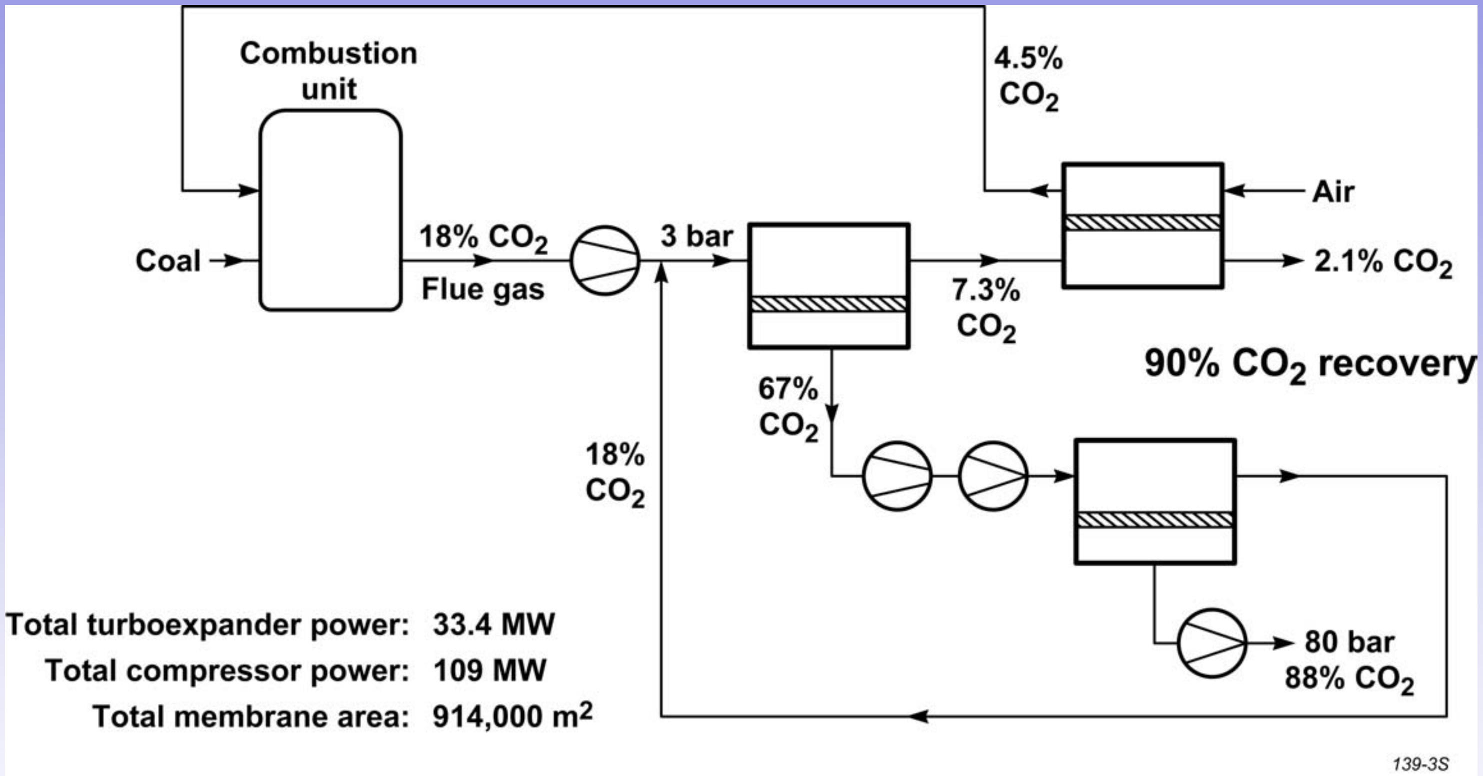
The MTR solution: Recycle gas to combustor



Total turboexpander power: 33.4 MW
Total compressor power: 109 MW
Total membrane area: 914,000 m^2

The MTR solution: Recycle gas to combustor



Designs	Membrane Area (000 m^2)	Power Consumption (MW)	Cost ($/ton of CO_2)
Option III MTR's	2,070 914	122 109	48 29

Conclusions

- Removal of CO_2 from flue gas is technically feasible, but economically challenging.
- CO_2 recycle to the combuster using counter-flow/sweep is a good way to reduce system cost.
- Membrane solution can recover 90% CO_2 at the expense of 18% power generated.
- Higher permeance membranes and lower cost membrane modules are desired.

MTR